05627-14-P

UNIVERSITY OF MICHIGAN
High Altitude Engineering Laboratory
Department of Aerospace Engineering

Program in Aeronomy

Status Report

Contract No. NASr-54(05)
1 June 1966 to 31 August 1966

Abstract

Three papers by E. K. Miller in the general area of plasma physics were completed or nearly so. One will be issued as a report, one was submitted to the Canadian Journal of Physics and one was submitted for presentation at the fall meeting of URSI.

Three Nike-Apache mass spectrometer payloads were prepared for flight at Ft. Churchill. Two flights were planned, one for quiet daytime conditions and one for strong auroral activity. The third payload was for back-up. The first flight was carried out successfully but the second was postponed after several holds for a suitable aurora.

Work on the electron density experiment continued with analysis of the antenna surface current and completion of the breadboard model of the instrumentation. Consideration is being given to the possibility of including antenna impedance in the flight measurements as an aid in interpreting the plasma resonance results.

Studies in the structure of the mesosphere continued with further analysis of the non-steady-state diffusion of oxygen. In measurements, new sphere drag coefficients in almost free molecule flow were obtained from an improved theoretical formula.

The distribution of atomic nitrogen from 100 to 280 km was computed from a comprehensive treatment of production and loss processes using up to date values of rate coefficients and reaction cross-sections.

Analysis of the dynamics of a small satellite was continued.

1. Composition Flight Instrumentation

Three payloads were prepared for flight. To obtain greater sensitivity at peak altitudes, the electrometer feedback resistor was increased by a factor of 10/3 to 10^{11} ohms. This necessitated the addition of compensation in the feedback network to maintain an acceptable rise time. The compensation was a distributed capacitance from the output to the feedback resistor element in the form of a parallel wire. Feedback was varied by varying the length of the wire. Final adjustment of the wire length was made immediately prior to neutral calibration, setting for optimum response to a typical staircase spectrum. In order to bring the larger signals expected at lower altitudes within the range of the electrometer, the emission regulator was modified to regulate at values of approximately 0.2 and 2.8 ma alternately. These values were individually adjusted on each payload to yield a tenfold change in sensitivity. Resolution adjustment was made by setting the DC-AC ratio for 80% transmission of the Argon peak. This is judged to be an acceptable compromise between high resolution and high transmission.

Each payload was calibrated by adjusting the dynamic pressure in a vacuum system from the ultimate vacuum (about 10^{-6} mm Hg) to about 10^{-3} mm Hg using an adjustable air leak and then returning to the ultimate vacuum. A calibration of the massenfilter in ambient ion analysis was attempted by operating it at the correct potentials while a beam of ions from a separate generator was directed at the inlet end. An absolute calibration was never obtained, however, due to the complexities of the processes within the system and the resultant uncertainties. As in the case of other investigators, the test we performed was merely a qualitative operational check rather than a calibration. Having conceded this point, the test was abandoned on the basis that the neutral mode calibrations had yielded an adequate qualitative check and there was little to be gained by demonstrating analysis capability upon yet another source of ions. Operating potentials of the massenfilter elements during ion analysis were checked on all payloads, however.

Complete environmental tests were conducted at GSFC. Flight test of NASA 14.96 UA was originally scheduled for launch 1400 hours CDT, 8 July 1966. A failure in a receiver at the Prince Albert radar site caused postponement of the test. In addition, lack of ionosonde data at higher altitudes due to a heavy electron density at 100 km which blanketed higher signal returns would probably have been the cause of a postponement. The launch was rescheduled for 1400 hours CDT on 11 July and was launched without further incident at 1418:00.156 hours CDT. Peak altitude as obtained from Prince Albert radar was approximately 204 km at 226 seconds. Telemetry signal quality was good except for a complete loss of signal between 54.7 seconds and payload ejection at 74.8 seconds. Since all other systems operated successfully, no important data were lost in this period. It is assumed a failure in the shroud antenna system occurred.

Neutral composition spectra were successfully obtained. Some degradation by what appeared to be contaminants and a slower electrometer response appeared. The contaminants were believed to originate from range supplied "absolute" alcohol used to clean the instrument which was subsequently determined to be merely of liquor quality. Ion data were quite poor due to a high noise level and low sensitivity. Only the major constituents can be obtained.

NASA 14.97 UA was scheduled for launch in strong auroral activity during the night of 11-12 July. The countdown was brought to X-20 minutes and held there while an auroral monitor was kept. An even considered "strong" for that season and portion of the solar cycle occurred at 2300 hours CDT but had attenuated to a level too low to warrant a launch by the time the countdown had reached "zero." The launching was postponed in the early morning hours due to lack of any further substantial auroral activity.

Post-flight examination of the ambient ion spectral data obtained from NASA 14.96 UA resulted in cancellation of the 14.97 UA launch so that the equipment could be returned to the laboratory and steps taken to increase the sensitivity and reduce the noise.

2. Electron Density Measurements

The preparation of the manuscript for a report titled "Excitation of Surface Currents on a Plasma-Immersed Cylinder by Electromagnetic and Electrokinetic Waves" by E. K. Miller was completed during the quarter. The report is an expanded version of the two papers recently published in Radio Science. It is anticipated that the report will be sent to the printer during the next quarter. A paper titled "Surface Current Excitation on an Inhomogeneously-Sheathed Plasma-Immersed Cylinder by Electromagnetic and Electrokinetic Waves" by E. K. Miller was submitted to the Canadian Journal of Physics. This material will also be prepared as a report to be issued by the High Altitude Engineering Laboratory during the next quarter. An abstract was prepared and submitted to the Fall 1966 URSI meeting, titled "The Impedance Variation about the Plasma Frequency of an Infinite Cylindrical Antenna in a Lossy Compressible Plasma." The preparation of a report dealing with the scattering cross-section of the plasma-immersed cylinder will be completed in the next quarter.

The main effort of the antenna analysis during this quarter has been devoted to the computations. A numerical integration technique was developed which allows the evaluation of the nearly singular Fourier integrals which give the antenna surface current to the desired degree of accuracy. The program developed for this purpose will be useful for all the subsequent antenna calculations. This integration technique has also proven useful in evaluating the free-space infinite antenna impedance, a topic of current interest in the literature.

It is anticipated that the computations for the vacuum sheath model will be essentially completed during the next quarter, and that computation will be started for the zero temperature plasma and vacuum sheath model with a magnetic field parallel to the antenna axis. The outcome of these calculations should determine the course of the subsequent analysis. It appears however, that the inhomogeneous sheath model antenna calculations might be too lengthy (and thus costly) to be pursued; a decision on this will have to await the results of the vacuum sheath calculations.

Thermal compensation and final testing of the engineering model of the high level sweep frequency excitation generator was completed during this period. All subsections of the plasma resonance relaxation detector were also completed in breadboard form and placed in operation. A frequency marker module was also added to the system to improve the precision of the plasma frequency determination. The measured overall system electron density resolution at a plasma frequency of 500 kilocycles is less than 1 part in 100. At higher electron densities, the resolution is even better. This is more than adequate since it is doubtful that a measurement of electron density to better than 1% is particularly meaningful.

As the theoretical work and system design has proceeded on the electron density measurement, it has become evident that a measurement of the antenna impedance would also be valuable in our interpretation of the results of this experiment. A modest amount of design effort has accordingly been allocated to this problem. The major design difficulty is posed by the wide frequency range (30:1) over which the system must operate. It is expected that breadboard circuits will be in operation during the next quarter which will permit the measurement of the absolute magnitude of the antenna impedance change over a range of at least 100 to 1 from 300KC to 10 megacycles. Also during the next quarter, the remainder of the system will be completed and operating in engineering model form. Consideration of the mechanical design of a suitable rocket borne antenna was postponed pending the selection of the type of rocket vehicle to be used for the electron density measurement.

Satellite Techniques

The feasibility of magnetic yaw torquing of a small gravity gradient stabilized satellite was continued during the period. Computer calculations of the pitch, roll and yaw axis time variations with a very simple torque control logic shceme have shown that yaw axis control is definitely feasible. The uncontrolled yaw oscillation of about $\pm 15^{\circ}$ can easily be reduced to $\pm 1^{\circ}$ and any degree of yaw offset from an arbitrary initial condition can be accomplished. This study was conducted for a single or two colinear boom configuration. With two swept back booms the yaw moment of inertia is greater and so torquing is more difficult, but not impossible. Next, the effect of aerodynamic stabilization at perigee was included to observe its effect on yaw control. Our conclusion is that if a yaw offset angle is required, it will be difficult to maintain in the polar regions because the magnetic dip angle approaches 90°. If it is necessary only to obtain a 180° yaw offset, the torquing power requirements are not excessive for a limited duty cycle. Fortunately, the scientific requirements for the satellite mission are quite compatable with this operational limitation. We now will investigate the response of orbit ellipticity, residual magnetic moments, and the orbit altitude versus lifetime effects on the gravity gradient - torque controlled stabilization system.

3. Mesospheric and Lower Thermospheric Structure

Work has continued on modifying the non-steady-state oxygen diffusion problem. The analytic solution to a diffusion equation for molecular oxygen with sources and sinks has been evaluated for special cases. The solutions were limited to calculations applying to the atmosphere above the turbopause because of numerical difficulties. The numerical problem has now been solved so that calculations can be made at lower levels.

The feasibility of including diurnal variations of parameters such as scale height gradient and nitrogen number density has been studied. At the moment the main effort is being concentrated on generalizing the method of solution.

Theoretical and experimental literature on sphere drag was examined to ensure that the best available data is being used to compute atmospheric density. It appears that a better theoretical formula can be found for almost free molecular flow at high altitude. Also at high altitude, the measurements of Aroesty show that the ratio of sphere wall temperature relative to stagnation temperature of the stream is an important factor that should be accounted for. The study of sphere drag data continues.

John Peterson attended the course "Stratospheric Circulation" at Texas Western College 11-22 July 1966.

4. Distributions of N and NO Between 100 and 280 Km

The distribution of N atoms between altitude range 100 and 280 km has been computed from reactions between constituent particles of the atmosphere and assuming their rate coefficients at laboratory temperature ($300^{\circ}K$) to be constant for the whole altitude range. It is also calculated from rate coefficients varying with temperature. It has been found that the latter distribution, which is considerably different from the former, gives a reasonably good profile.

The diffusion of N atoms through the atmosphere which is assumed to be the same as that for N through N_2, is also calculated after neglecting the temperature diffusion (as N atom density is calculated by equating its production and loss rates, the flux of N becomes zero). Since in many cases, reactions involving loss of N atoms lead to the production of NO molecules, the altitude distribution of NO molecules is also calculated. The computed N and NO distributions compare favorably with certain rocket experiments and laboratory data.

It is emphasized that since rate coefficients of certain reactions, for example, the coefficient of an ion-atom interchange reaction having large activation energy, may vary by several orders for the above altitude range, laboratory experiments should be carried out to obtain not only accurate rate coefficients but also their temperature variations.

5. Fiscal Information

Amount of Contract (through 31 March 1967)			$1, 386, 000.00
Transactions to 31 May 1966		$1, 147, 558.25	
Transaction 1 June 1966 to 31 August 1966			
Salaries & Wages	$56, 863.21		
Overhead	24, 366.21		
Materials and Supplies	4, 917.08		
Travel	6, 034.97		
Equipment	2.45		
Subcontracts	---------		
Total		$ 92, 183.92	
Total Transactions to 31 August 1966			$1, 239, 742.17
Balance as of 31 August 1966			$ 146, 257.83

Respectfully submitted,

L M Jones

L. M. Jones

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